

Project Report: Evolution of Atmospheric O₂, Climate and Biosphere – Rosemary C. Capo

Lead Team:	<i>Pennsylvania State University</i>
Project Title:	<i>Evolution of Atmospheric O₂, Climate and Biosphere – Rosemary C. Capo</i>
Project Investigator:	<u>Rosemary Capo</u>

Project Progress

Paleosols, preserved ancient soils, are significant to the study of past life, climate, and landscapes on Earth and as analogues for the environment in which terrestrial life might develop on other planets. However, interpretation of the ancient soil record presents many challenges, including difficulty constraining ages, overprinting by thermal events, and deformation of soil textures and structures. To gain insight into element mobility under different soil-forming conditions, M.S. student Amanda Reynolds investigated the geochemical and isotopic characteristics of Paleozoic paleosols and lacustrine sediments formed under varying redox environments. She found that reducing conditions within and between “redbed” paleosols and green gleyed paleosols with similar parent materials led to distinct Sr and Nd isotopic compositions. Ph.D. student Sherry Stafford returned to Finland for additional sampling of the ~2.3 Ga Hakkalampi paleosol of eastern Finland. Recent results, including isotopic and LA-ICPMS analysis with Associate Member Macpherson, suggest preservation of Sm–Nd isochrons that represent the time of soil formation, and a decoupling of iron loss and redox sensitive trace elements, including REE. Moreover, initial strontium isotope data indicate that the Rb–Sr system can be used to determine the age of metamorphism that partially overprinted paleosol geochemistry.

Terrestrial carbonate minerals formed in soil profiles (e.g., calcretes) can also record paleoenvironmental conditions. In collaboration with Associate Member Oliver Chadwick and Ph.D. student Charles Whipkey, soil carbonate was examined in three Quaternary environments: (1) New Mexico soil (dust dominated); (2) Hawaii chronosequence (basalt weathering), and (3) South Point, HI (marine influenced). Strontium isotope measurements were combined with micromorphologic studies, major and trace element analyses, and mass balance calculations in order to examine the locations, rates and mechanisms of mineral weathering within arid to semiarid soils and identify shifts in the relative contributions of silicate weathering and exogenous input to the soil cation budget as a function of climate change. These results can be

applied to Precambrian soil carbonates to understand early Earth environments.

Highlights

- Variations in soil redox conditions can result in distinct Nd and Sr isotopic signatures that are preserved in paleosols.
- Isotopic analysis of Precambrian paleosol material from two Hakkalampi sites record the age of soil formation at 2.3 Ga, and a subsequent metamorphic event at 1.8 Ga.
- Although continental soil carbonate is dominated by calcite, magnesian calcite (up to 12% MgCO_3) and stoichiometric, well-ordered dolomite can develop subaerially within 10^5 years in a non-carbonate substrate, with minimal influence from seawater or atmospheric input from dust or rain. This is relevant for interpretation of the origin of carbonate minerals that could be found in ancient soils on Earth as well as on Mars or other planetary bodies.

Roadmap Objectives

- [Objective No. 5: Linking Planetary Biological Evolution](#)
- [Objective No. 11: Origin of Habitable Planets](#)
- [Objective No. 12: Effects of Climate Geology on Habitability](#)
- [Objective No. 14: Ecosystem Response to Rapid Environmental Change](#)

Field Expeditions

Field Trip Name: Mission to Early Earth Pilbara Excursion	
Start Date: 07/01/2001	End Date: 07/13/2001
Continent: Australia	Country: Australia
State/Province:	Nearest City/Town: Pt. Hedland
Latitude:	Longitude:
Name of site(cave, mine, e.g.): Pilbara district	Keywords:
Description of Work: Examination and sampling of Precambrian paleosols, stromatolites and sediments in Pilbara district, followed by NAI workshop at Macquarie Univ., Sydney	
Members Involved: Led by Roger Buick (NAI–UW) and Ariel Anbar (NAI–Rochester). Participants: Sherry Stafford (Univ. of Pittsburgh) and members from numerous NAI teams.	
Field Trip Name: Dunkard paleosol	

Start Date: 07/01/2001	End Date: 11/01/2001
Continent: N. America	Country: USA
State/Province: WV	Nearest City/Town: Smithburg
Latitude: 43.48 N	Longitude: 17.52 E
Name of site(cave, mine, e.g.): outcrop	Keywords: redbed, paleosol, Paleozoic
Description of Work: Sampling and description of Dunkard basin paleosols exposed in roadcuts	
Members Involved: Amanda Reynolds (Univ. of Pittsburgh), Rosemary Capo, (Univ. of Pittsburgh)	

Field Trip Name: Central PA paleosols

Start Date: 09/29/2001	End Date: 09/29/2001
Continent: N. America	Country: USA
State/Province: PA	Nearest City/Town:
Latitude:	Longitude:
Name of site(cave, mine, e.g.):	Keywords: paleosol
Description of Work: Sampling and examination of paleosol exposed in roadcuts	
Members Involved: Led by H. Ohmoto (PSU); participants included R. Capo. B. Stewart (U. Pittsburgh)	

Field Trip Name: Hokkalampi paleosol

Start Date: 05/10/2002	End Date: 05/22/2002
Continent: Europe	Country: Finland
State/Province:	Nearest City/Town: Helsinki
Latitude:	Longitude:
Name of site(cave, mine, e.g.): Nuutilanvaara/Paukkajanvarra	Keywords: Precambrian, paleosol
Description of Work: Sampling of paleosol parent material	
Members Involved: Sherry Stafford (Univ. Pittsburgh), J. Mlrmo (Geol. Survey of Finland)	

Field Trip Name: Kawaihae paleosol

Start Date: 05/29/2002

End Date: 05/29/2002

Continent: N. America

Country: USA

State/Province: Hawaii

Nearest City/Town: Waikoloa

Latitude:

Longitude:

Name of site(cave, mine, e.g.): roadcut

Keywords: carbonate, soil

Description of Work: Sampling of pedogenic carbonate and weathered basalt

Members Involved: R. Capo, B. Stewart, O. Chadwick

Cross Team Collaborations

Mission to Early Earth (MtEE) Focus Group

We are involved in the NAI Mission to Early Earth (MtEE) focus group, which is seeking funding for selection and drilling of pristine samples of Precambrian sediments and paleosols. As part of this research endeavor, Ph.D. student Sherry Stafford received a NAI Director's research grant for her field and laboratory studies of paleosols; this also funded her participation in the MtEE field trip to Australia, and participation in an NAI workshop there. We are currently negotiating to provide radiogenic isotope support for the initial core samples that are obtained from a proposed drilling project in Australia. We are collaborating with Ariel Anbar of the University of Rochester (Harvard and Jet Propulsion Laboratory (JPL) teams) on isotopic investigations of Precambrian paleosols.